XFEL.EU TR-2012-005

TECHNICAL REPORT

Summer 2012 Vibration Measurements Report

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for the Technical Coordination group

at European XFEL

Contents

1 Objective

In the current XFEL project, the vibration in the tunnels is one of the important factors which will affect the reliability and stability of the future laser facilities and experiment results. Understanding the vibration behavior of the tunnels will help the XFEL experts and engineers stabilize the synchrotron light sources in the design phase as well as in the operating phase.

Since several sites in the tunnels are nearly finished this summer, vibration measurements were taken from those points to collect the vibration data and contribute the data to the existed vibration data base in Desy. In this report, data from some locations will be showed and compared.

2 Measurement sites

Measurement sequence	Location	Date	Measurement period
1	XHEXP1	June 15th,2012	25 hours
2	XTL 100m	June 30th, 2012	113 hours
3	XTL 1000m	July 4th, 2012	41 hours
4	XTD6	July 6th, 2012	68 hours
5	XTD1	July 9th, 2012	41 hours
6	XTL 2000m	July 19th, 2012	46 hours
7	XTIN	July 24th, 2012	25 hours

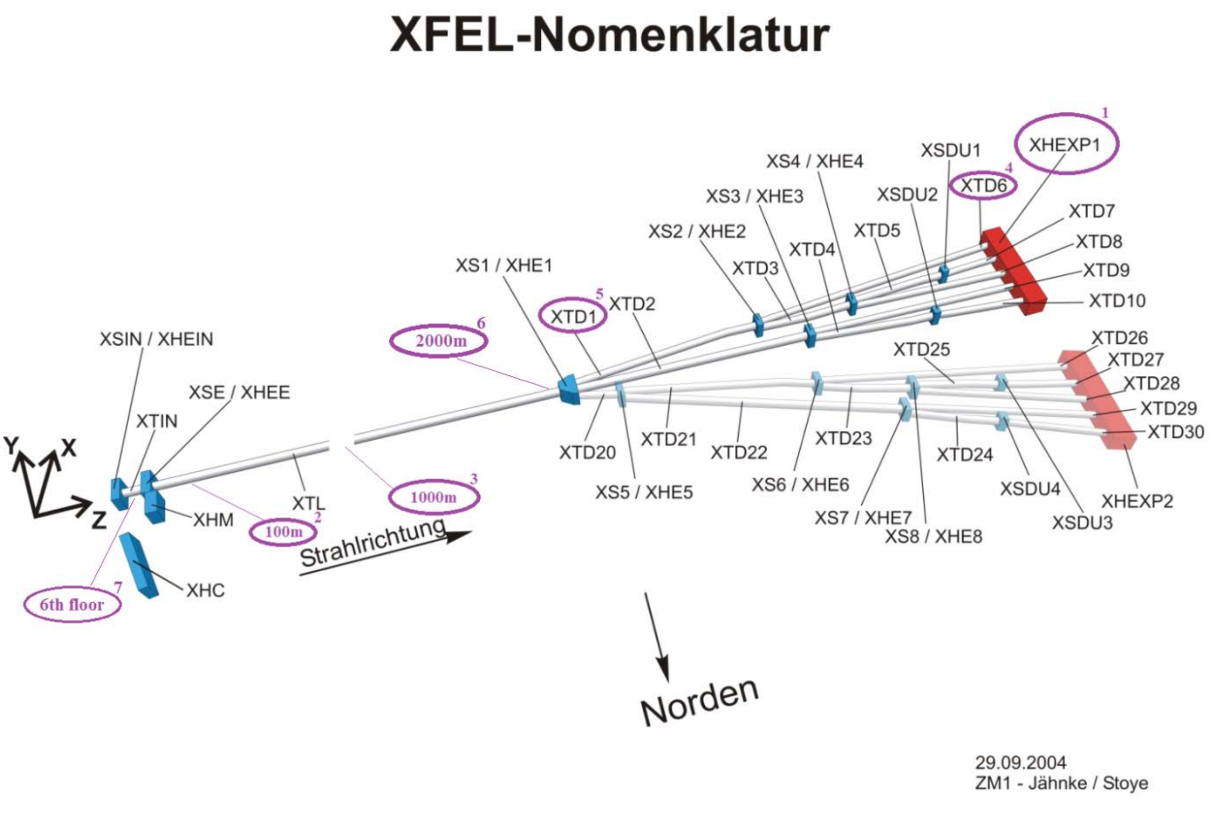

Fig. 1. Measurement sites

3 Devices and the Set Up

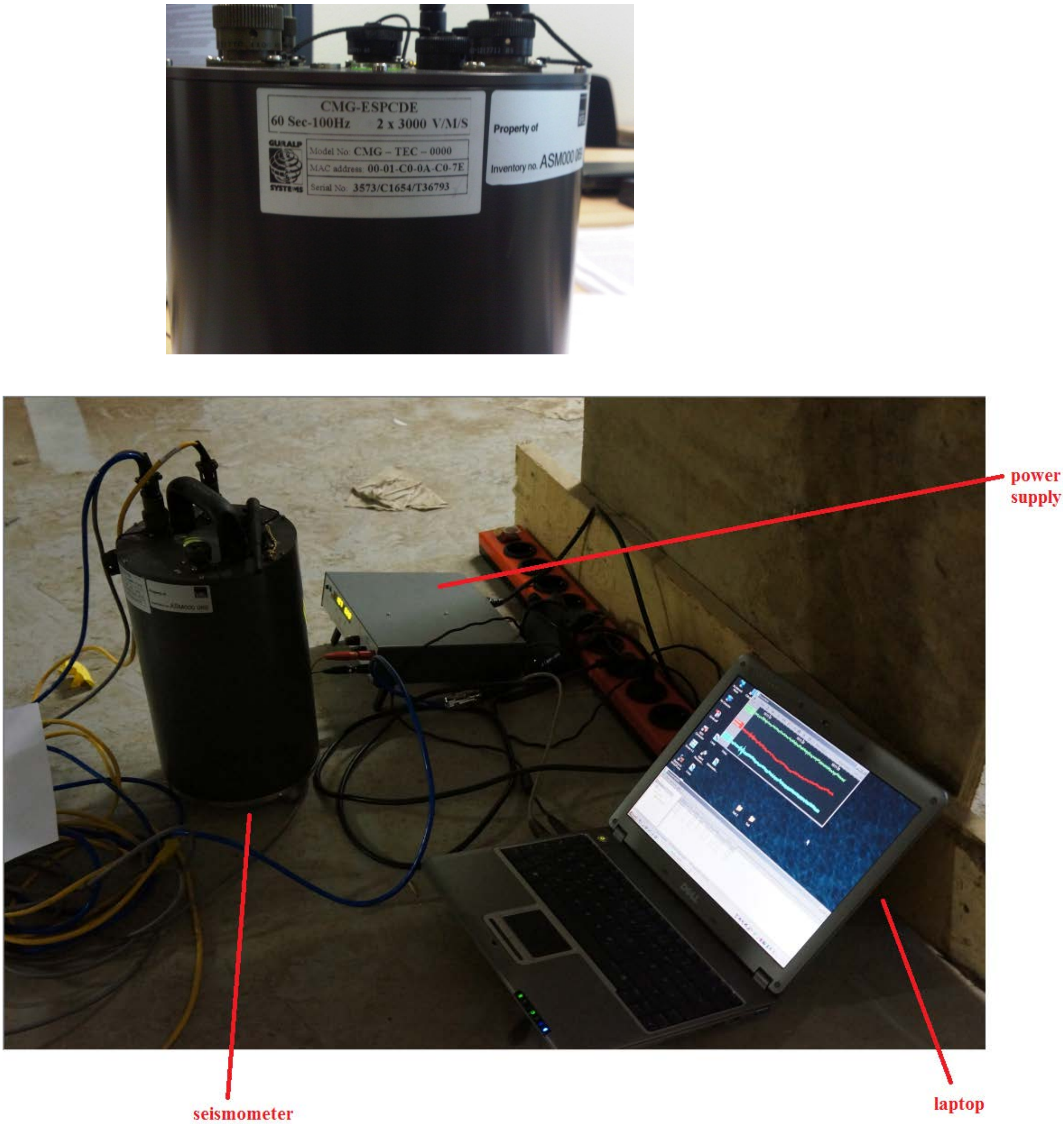

Fig. 2. *The Guralp seismometer and other devices*

The main device we use is the seismometer made by Guralp Systems, model CMG-ESPCDE. The device must be accompanied by a computer which has the control software named SCREAM4.5. Besides, a power supply (13V) and a USB - COM convertor are also required.

When arriving a measurement location, the power supply needs to be plugged into a power source (220V) first. Then the seismometer needs to be connected with the power supply (13V) and the laptop. We have to make sure the arrow on the device's handle heading north and the level bubble is in the center. Next, SCREAM4.5 is opened and the device in the COM port can be found in the setup option. After the computer recognizes the device, centering the mass of the seismometer is required before actual recording the data to avoid major errors. When clicking the recording button, the data will be saved as .ufa files in the three folders according to north, east and Z directions. For our measurements, we setup the software to generate a new .ufa file every 10 minutes which means every file contains 10 minutes' raw data. The sampling rate is 200Hz (200 points per second). The .ufa files are automatically named by the internal computer time which is 77 minutes slower than Hamburg local time. The actual recording time can be found in the file details.

Tips for trouble shooting

1. Make sure the seismometer is unlocked from inside. Using the SCREAM4.5 to unlock the device.
2. Center the mass of the seismometer after making the arrow on the device handle head north and the level bubble is in the center.
3. Choose the right baud rate for the seismometer. Our seismometer works with the baud rate of 115200
4. When plug the power supply to the power source, wait some time to let the voltage go up to 13V.
5. Make sure the USB convertor is working and check the computer already installed the driver for the convertor.

4 Data analysis

Python codes written by Dr. Gerd Wellenreuther were used to analyze the data from the seismometer. The following graph is what the results look like.

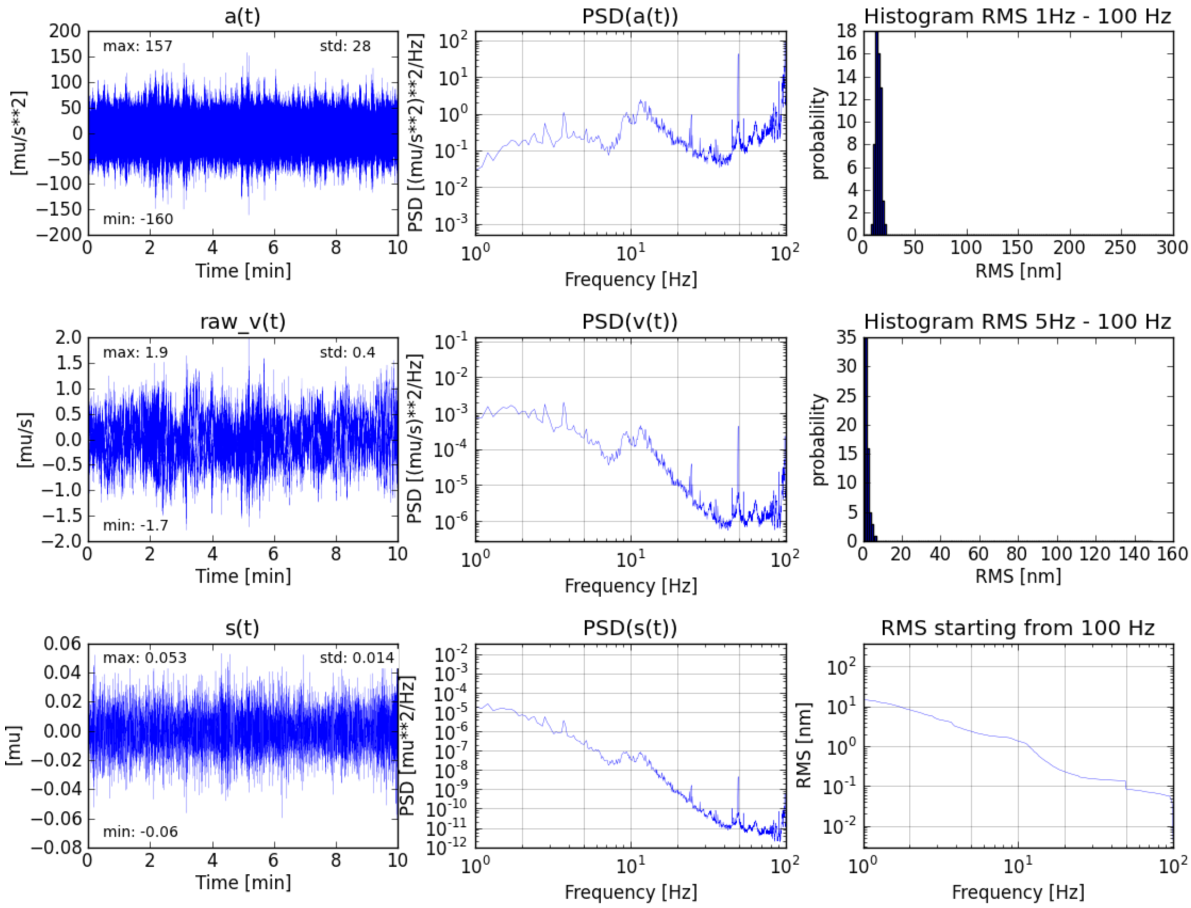

Fig. 3. *Results at XTL 2000m, 3:00am on 18-7-12*

The raw_v(t) is the raw velocity data which is directly read from the files generated by the seismometer. The raw data contains all the frequencies, even including every small ones which respond for short time drifts.

From the raw_v(t), the fast-Fourier-transform (FFT) of s(t) and a(t) are created by the integration in Fourier-space. The graphs of s(t) and a(t) are the back-transformated of s(t) and a(t) (FFT^{-1}). They are not complete but contain only those frequencies with respect to the time in the horizontal exis. Moreover, the lower frequencies (in the range of 0.01-1Hz) are cut off.

The PSD plots stand for power spectral density or energy spectral density. The spectral density of the wave, when multiplied by an appropriate factor, will give the power carried by the wave, per unit frequency, known as the power spectral density (PSD) of the signal. Power spectral density is commonly expressed in watts per hertz (W/Hz).

The RMS means the root mean square, also known as the quadratic mean. The RMS gives the standard deviation of the quantity over a range of frequencies. The lowest frequencies give the biggest displacements. In Fig. 3, the RMS of the displacement is around 20nm at 1 Hz-100Hz. In the Python module, the RMS values obtained by the displacement values according to the following method. In the case of a set of n values (x_1, x_2,…, x_n), the RMS value is given by this formula:

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{n}\left({x_1}^2 + {x_2}^2 + \cdots + {x_n}^2\right)}$$

In order to compare the difference of the vibrations in quiet and noisy time on locations, the data files in 3 typical time periods in a day will be analyzed. They start at 3:00, 9:00 and 21:00. Each period is 10 minutes or 60 minutes. Since only one seismometer can be worked at the same time, the data from different locations has different date.

4.1 Z-direction results which represent the vibrations vertically at 3:00am, 9:00am, 21:00pm

3:00am: This is the most quiet time among the four time periods.

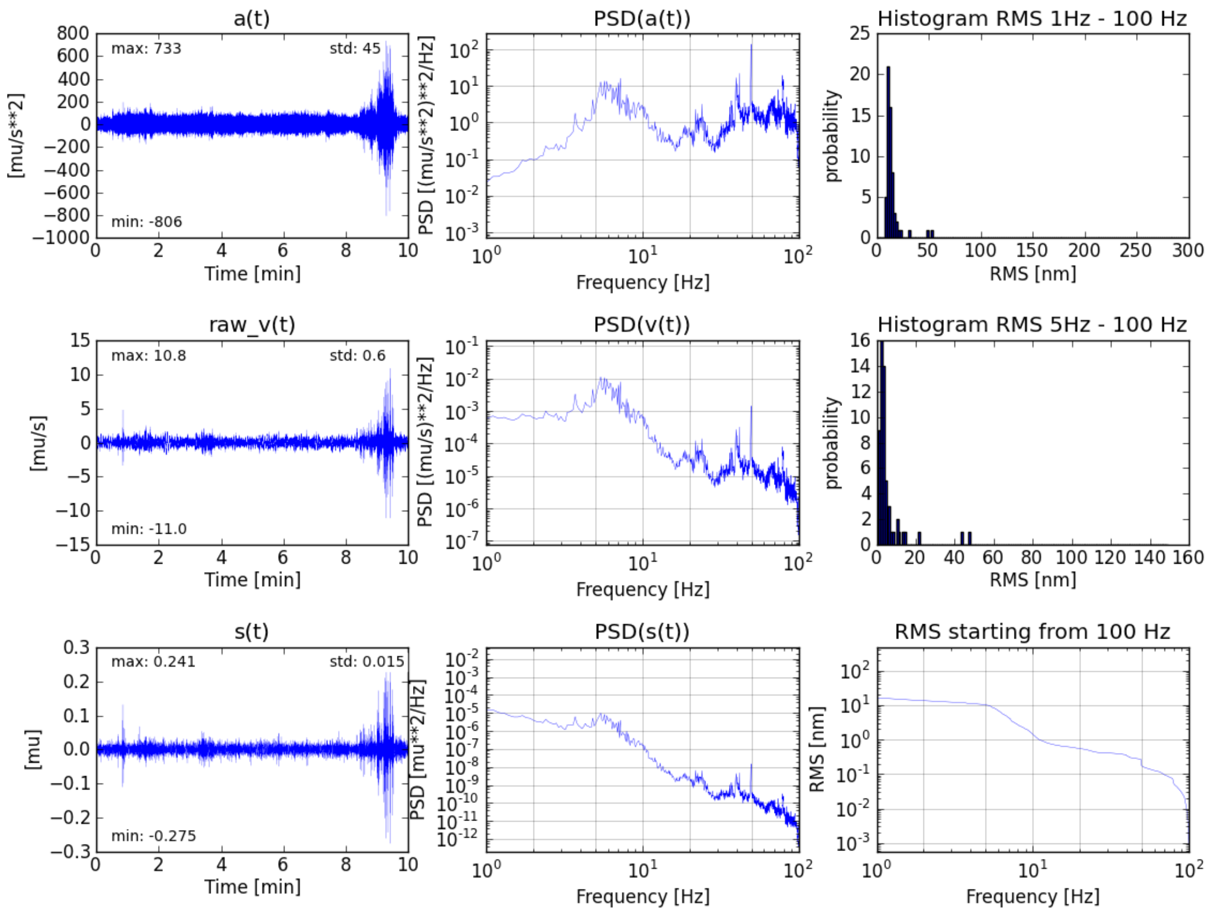

Fig. 4. *XHEXP1, 3:00am on 15-6-12*

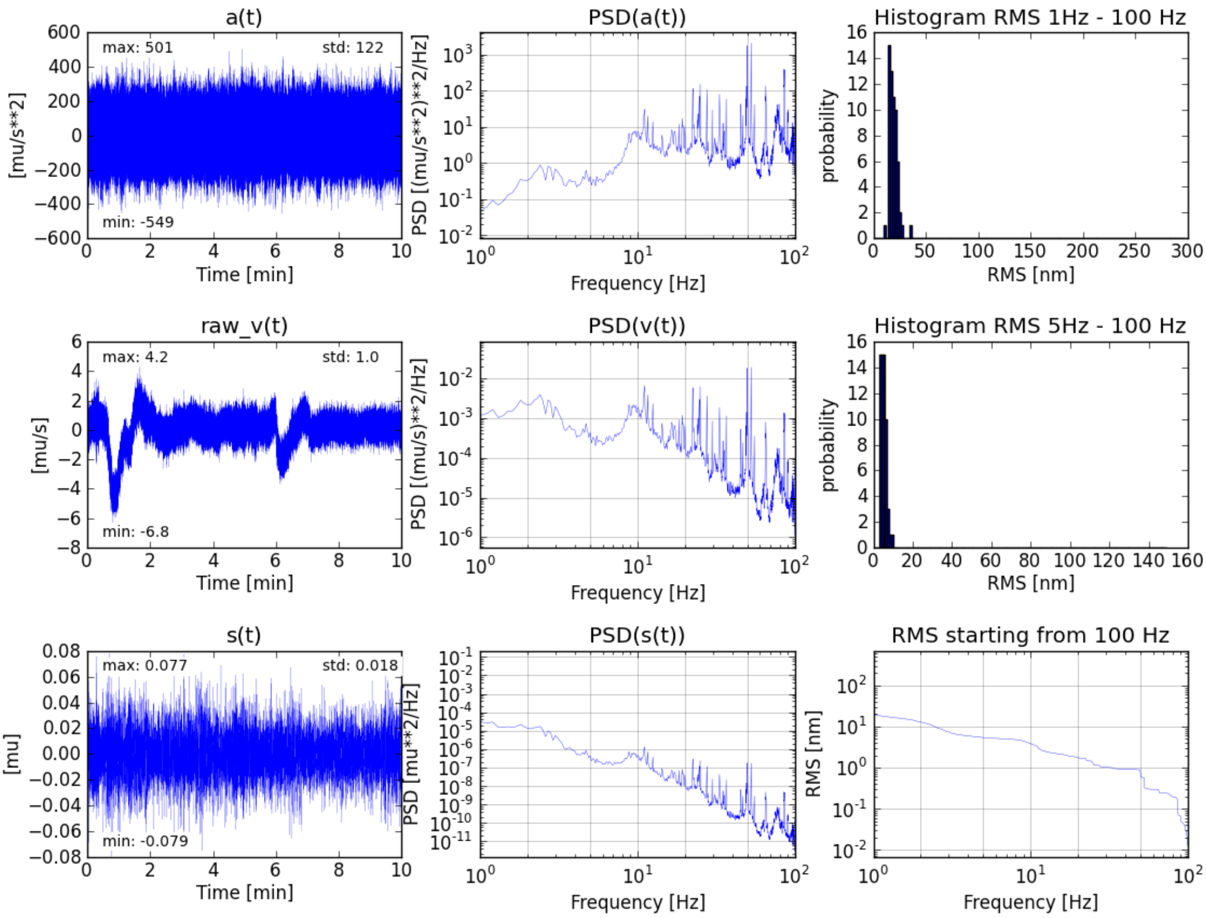

Fig. 5. *XTL at 100m, 3:00am on 30-6-12*

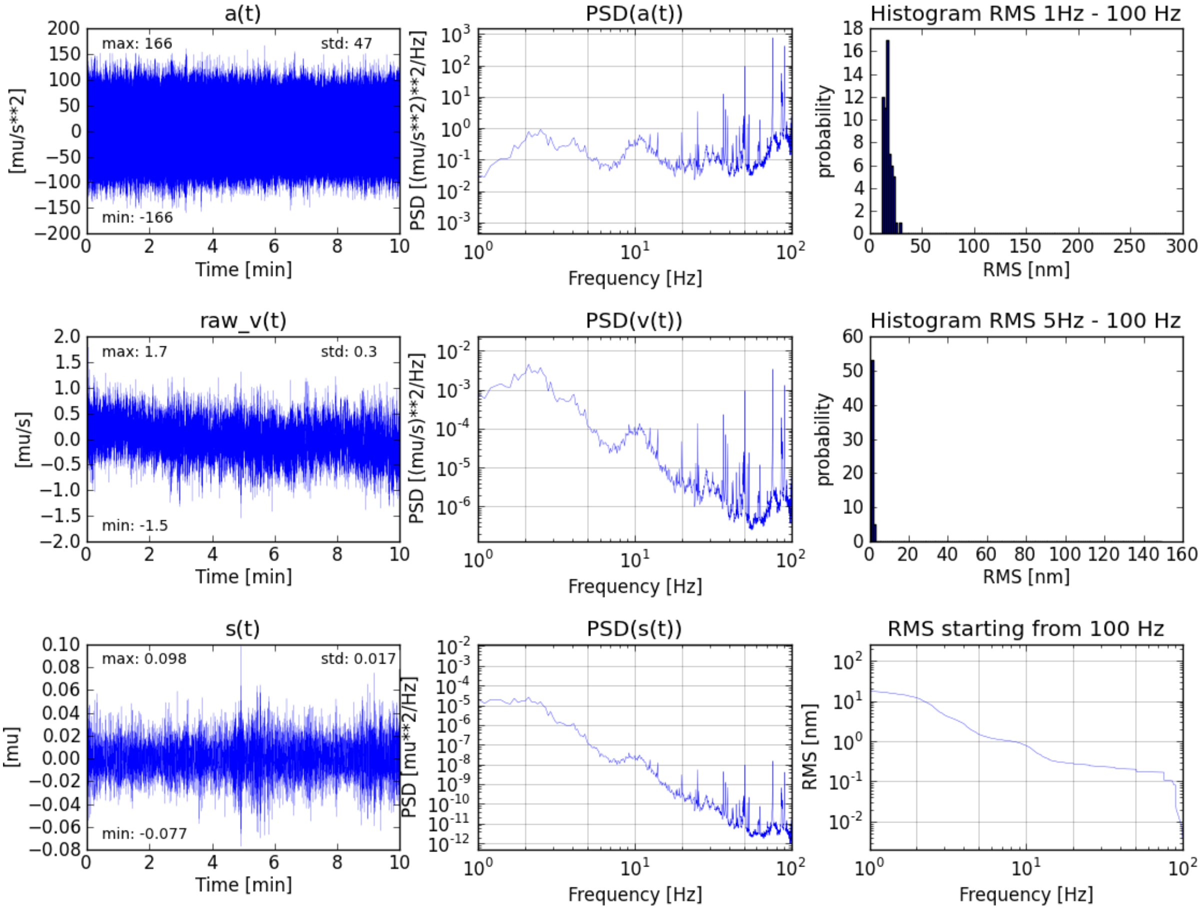

Fig. 6. *XTL at 1000m, 3:00am on 4-7-12*

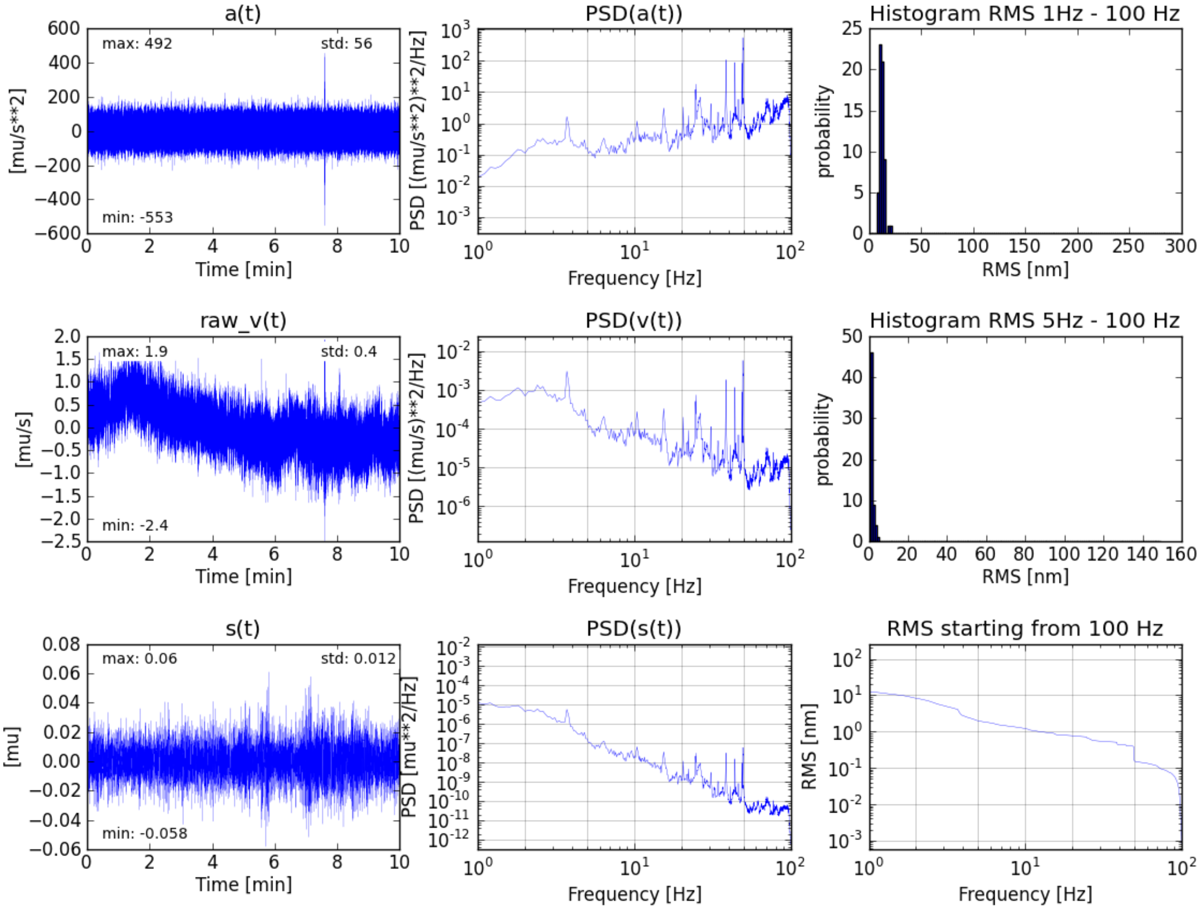

Fig. 7. *XTD6 at 1000m, 3:00am on 6-7-12*

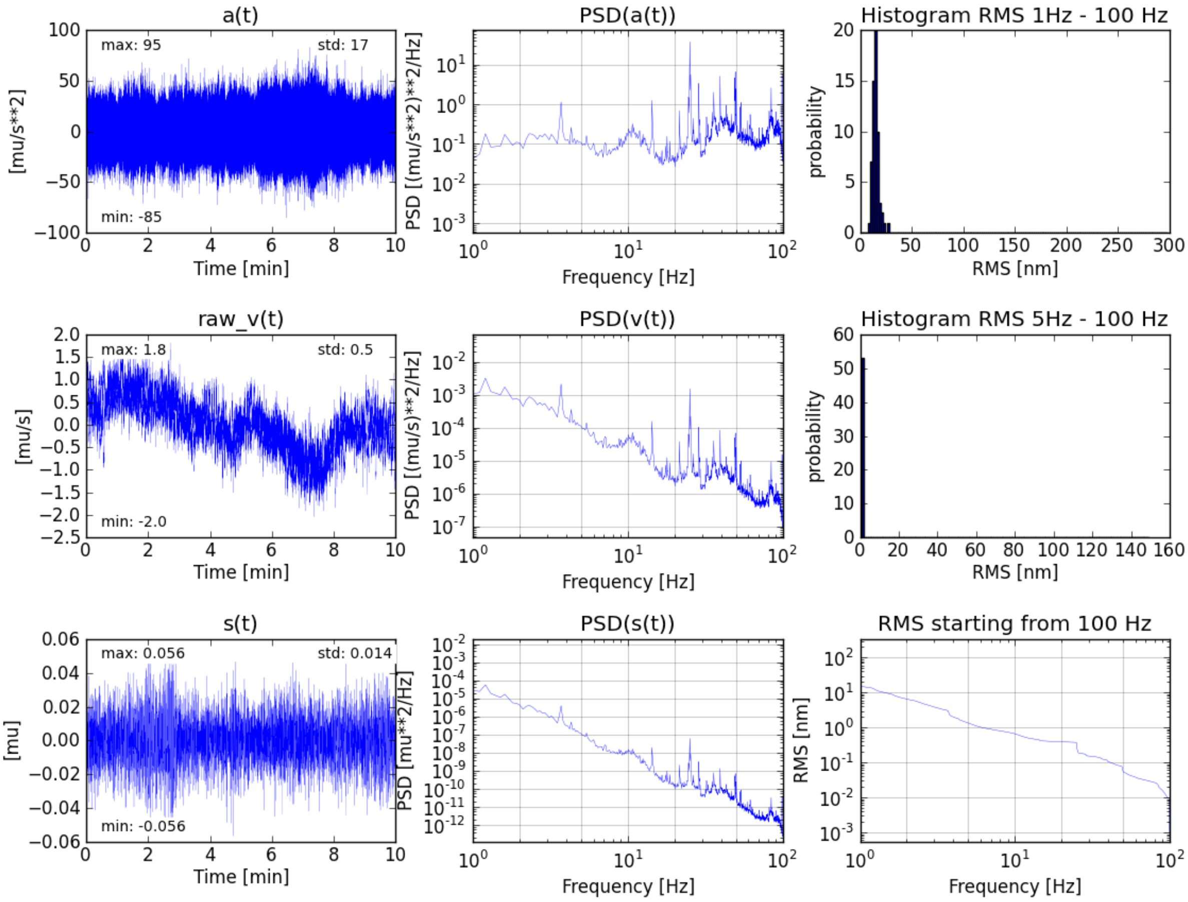

Fig. 8. *XTD1 at 300m, 3:00am on 13-7-12*

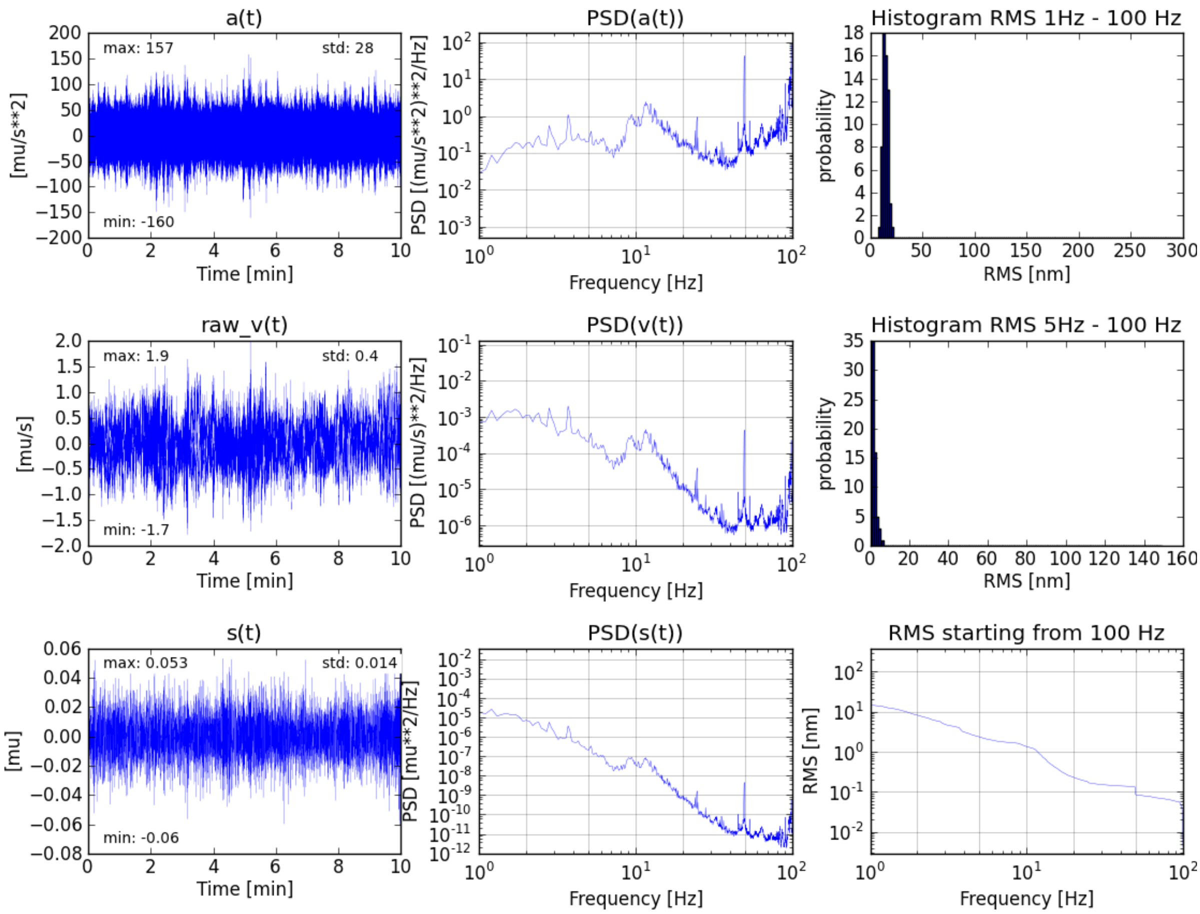

Fig. 9. *XTL at 2000m, 3:00am on 18-7-12*

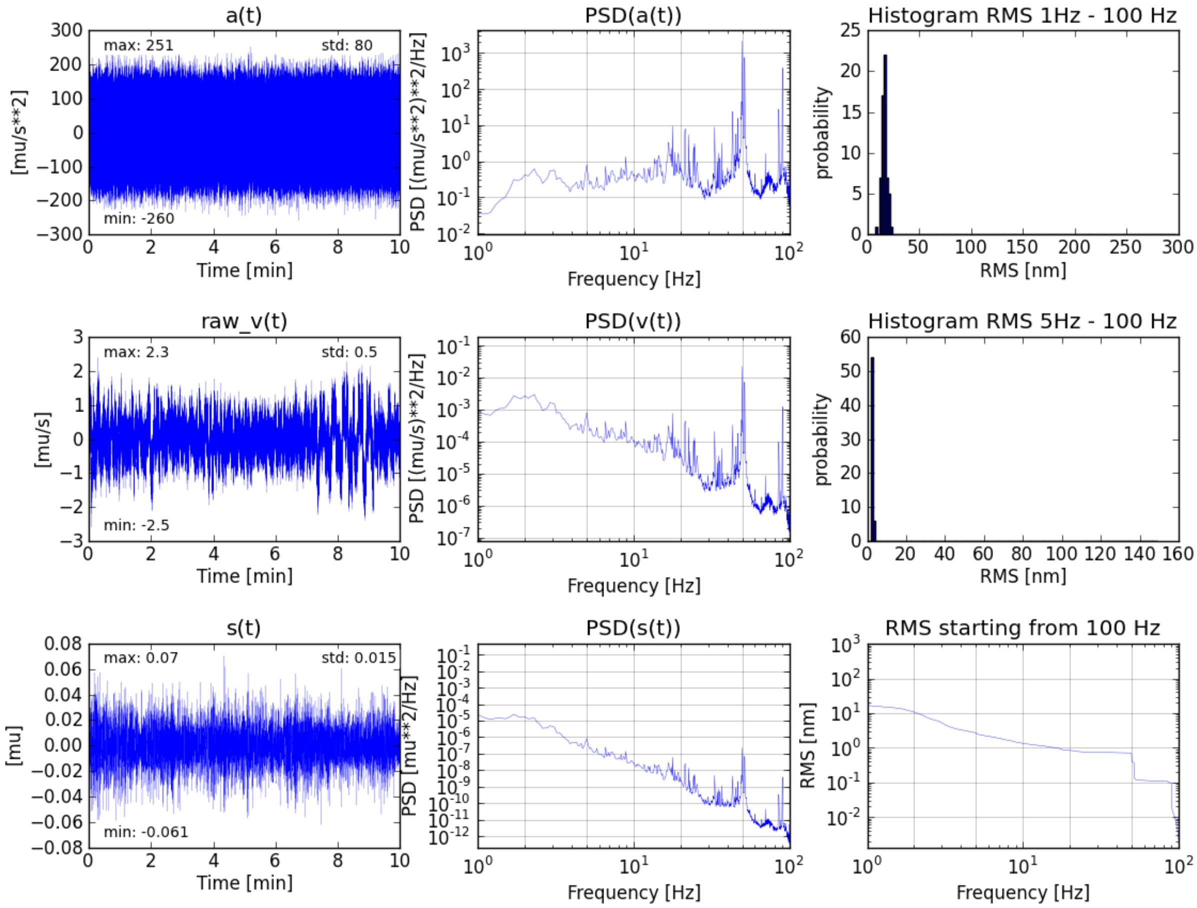

Fig. 10. *XTIN at 6th floor, 3:00am on 24-7-12*

9:00am: This is the working time period

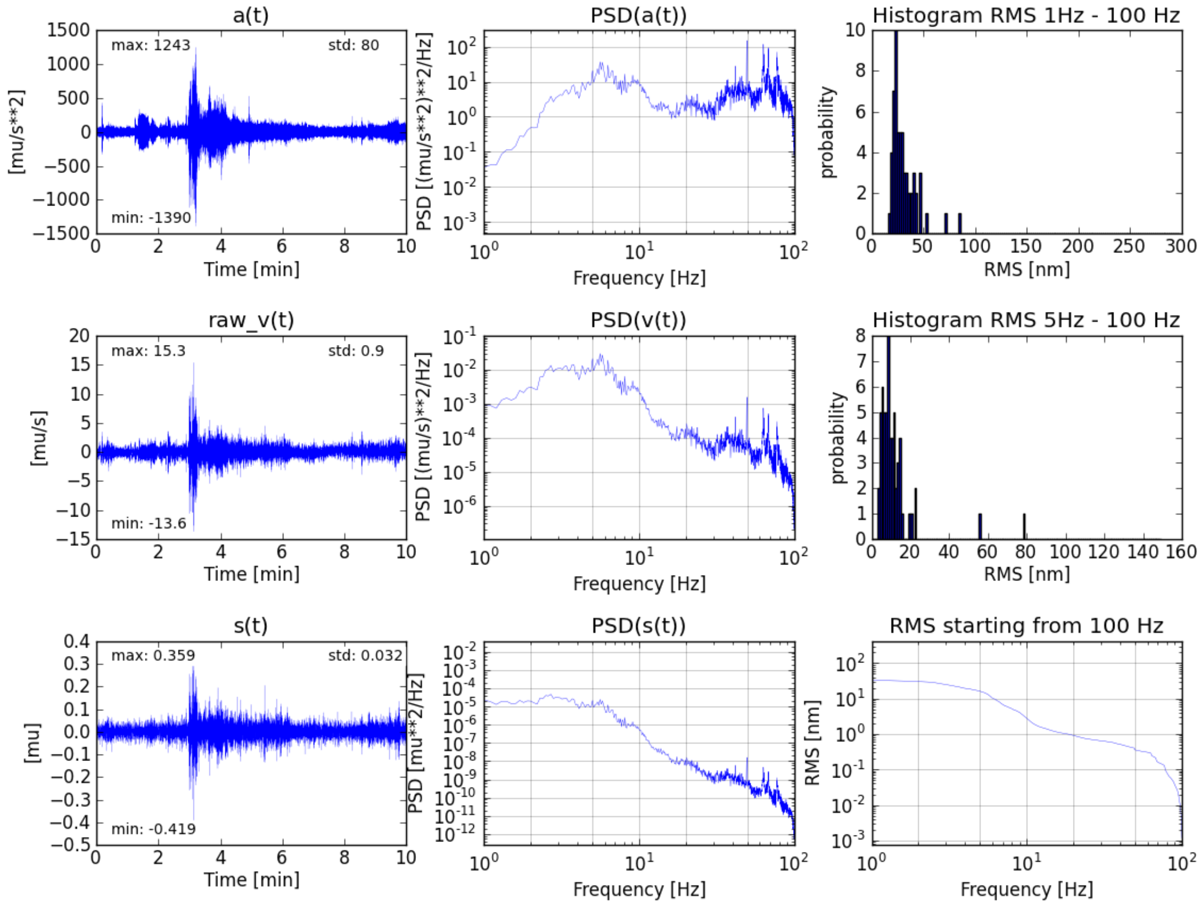

Fig. 11. *XHEXP1, 9:00am on 15-6-12*

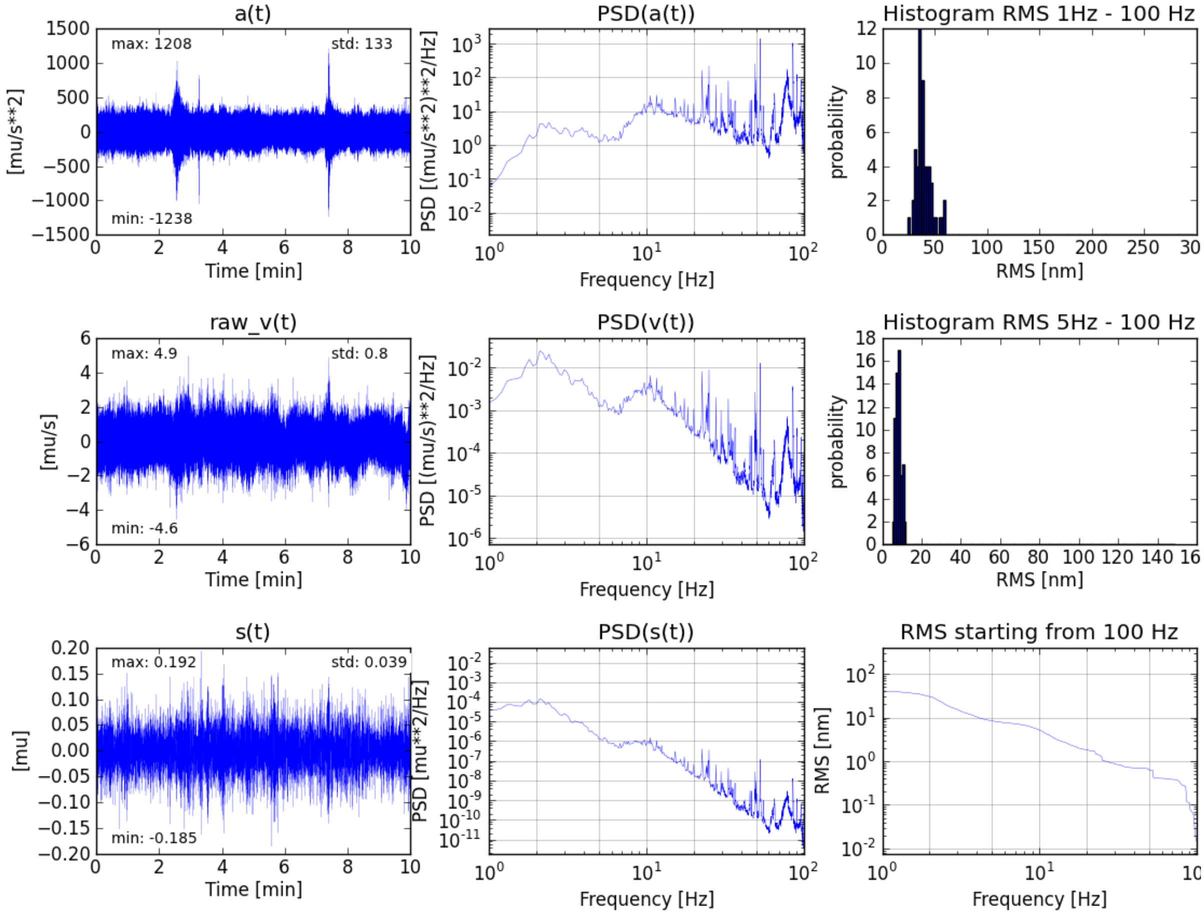

Fig. 12. *XTL at 100m, 9:00am on 30-6-12*

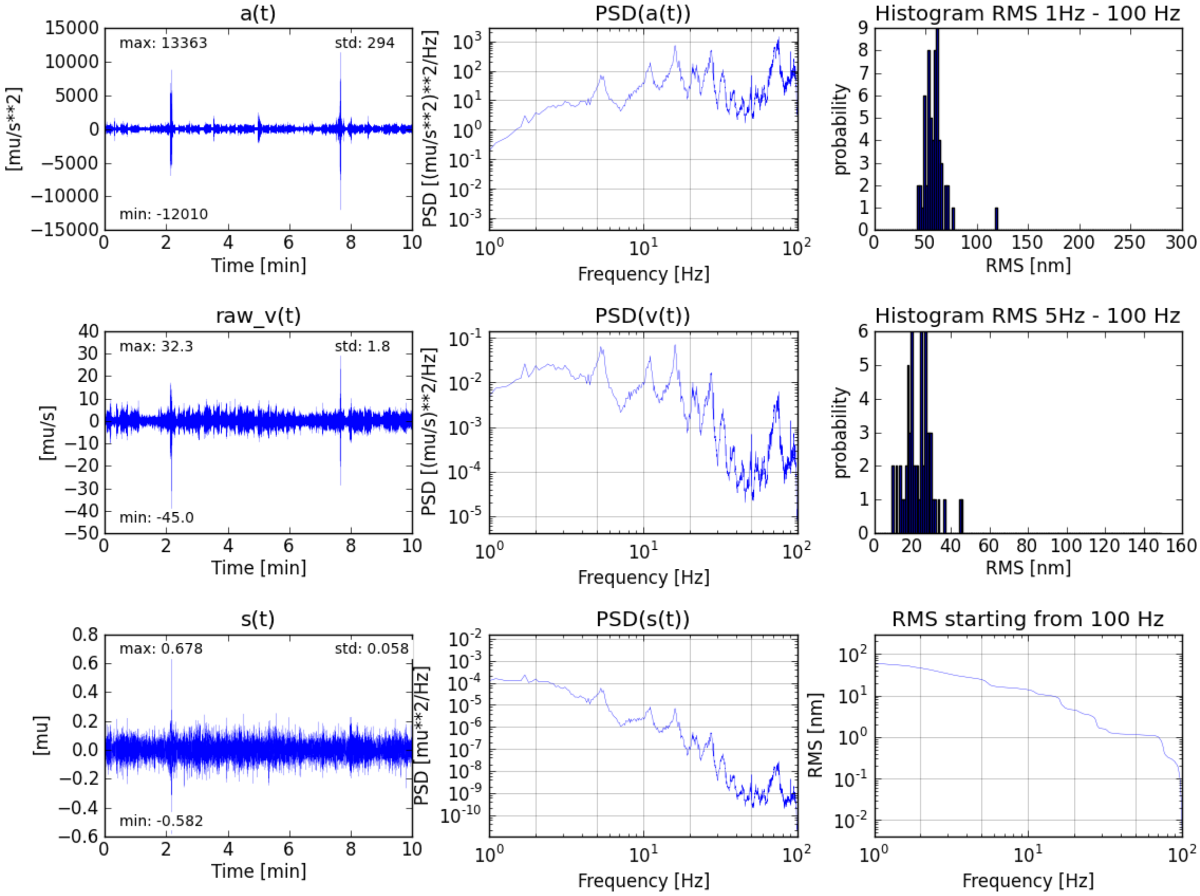

Fig. 13. *XTL at 1000m, 9:00am on 4-7-12*

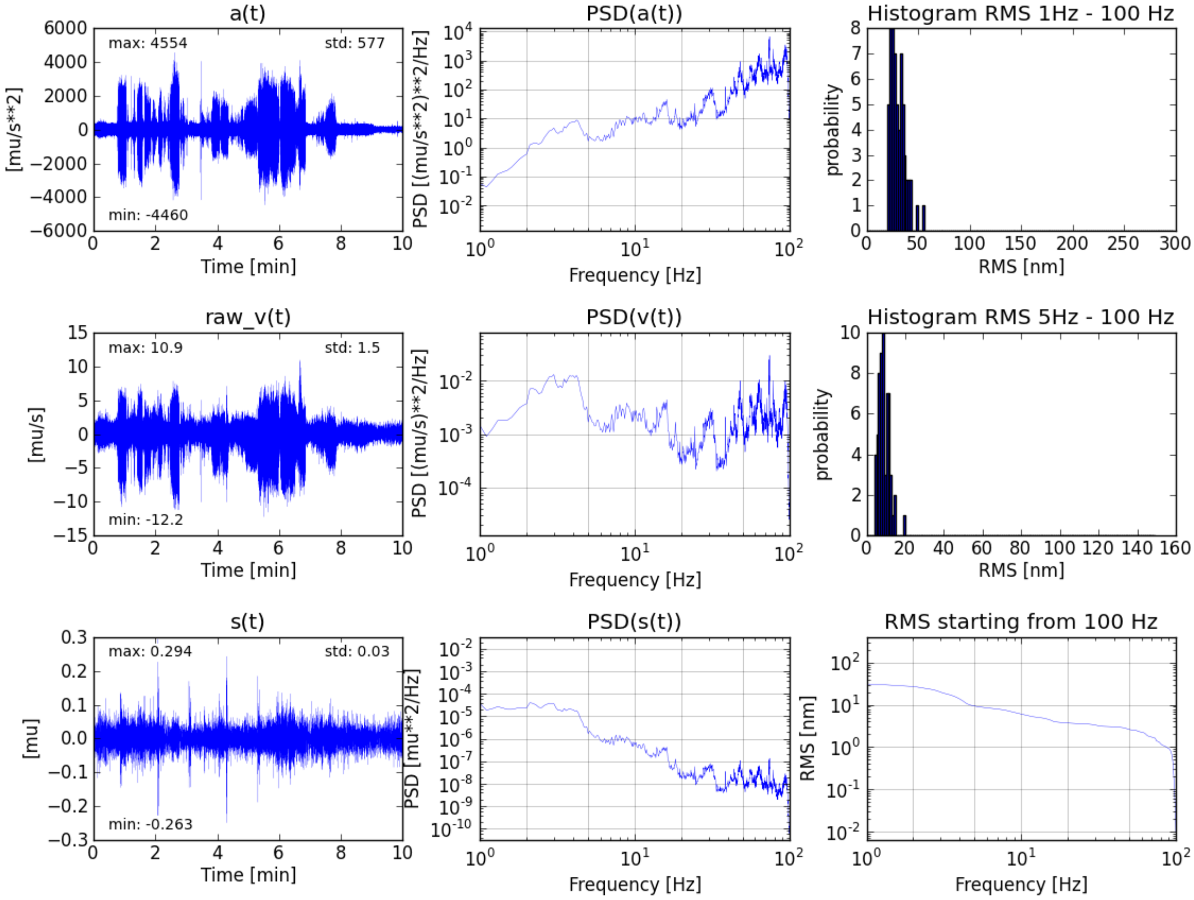

Fig. 14. XTD6, *9:00am on 6-7-12*

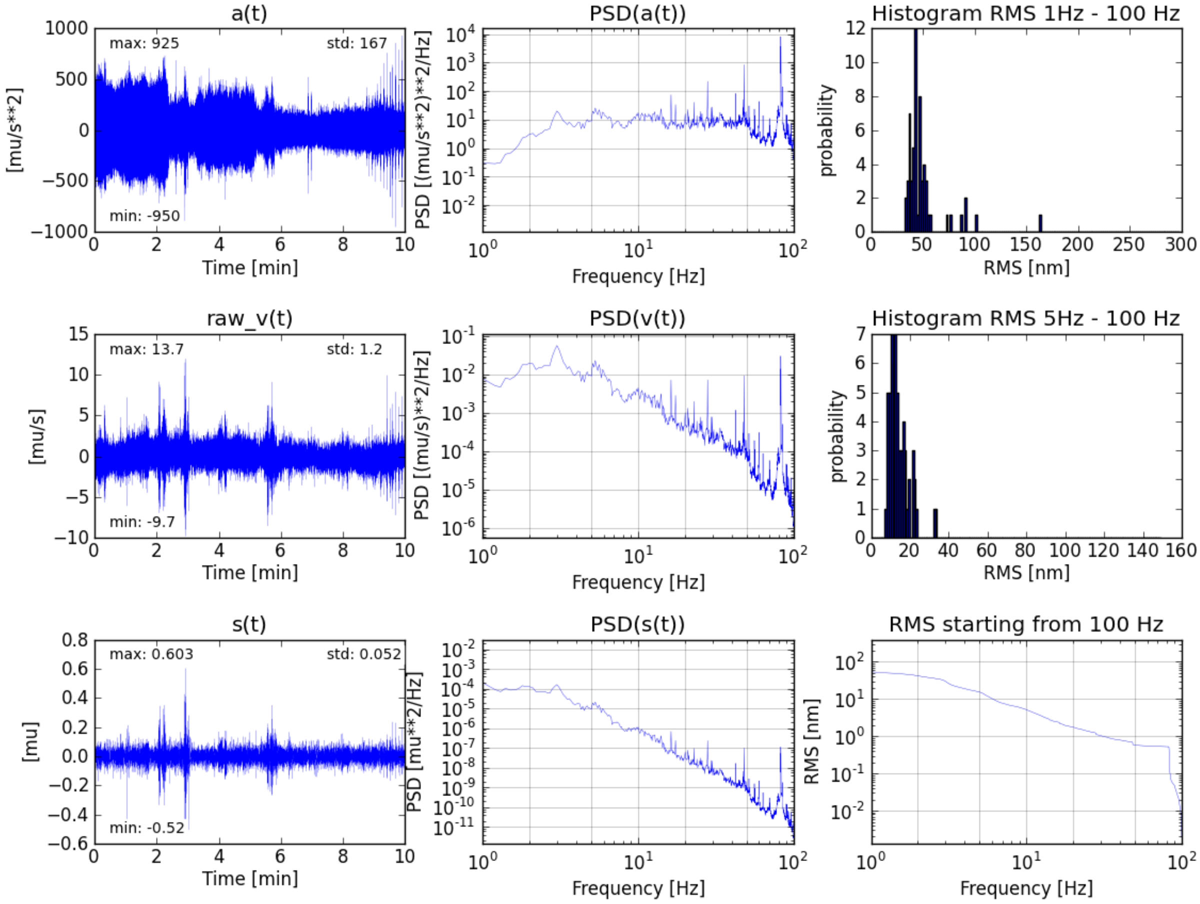

Fig. 15. *XTD1 at 300m, 9:00am on 13-7-12*

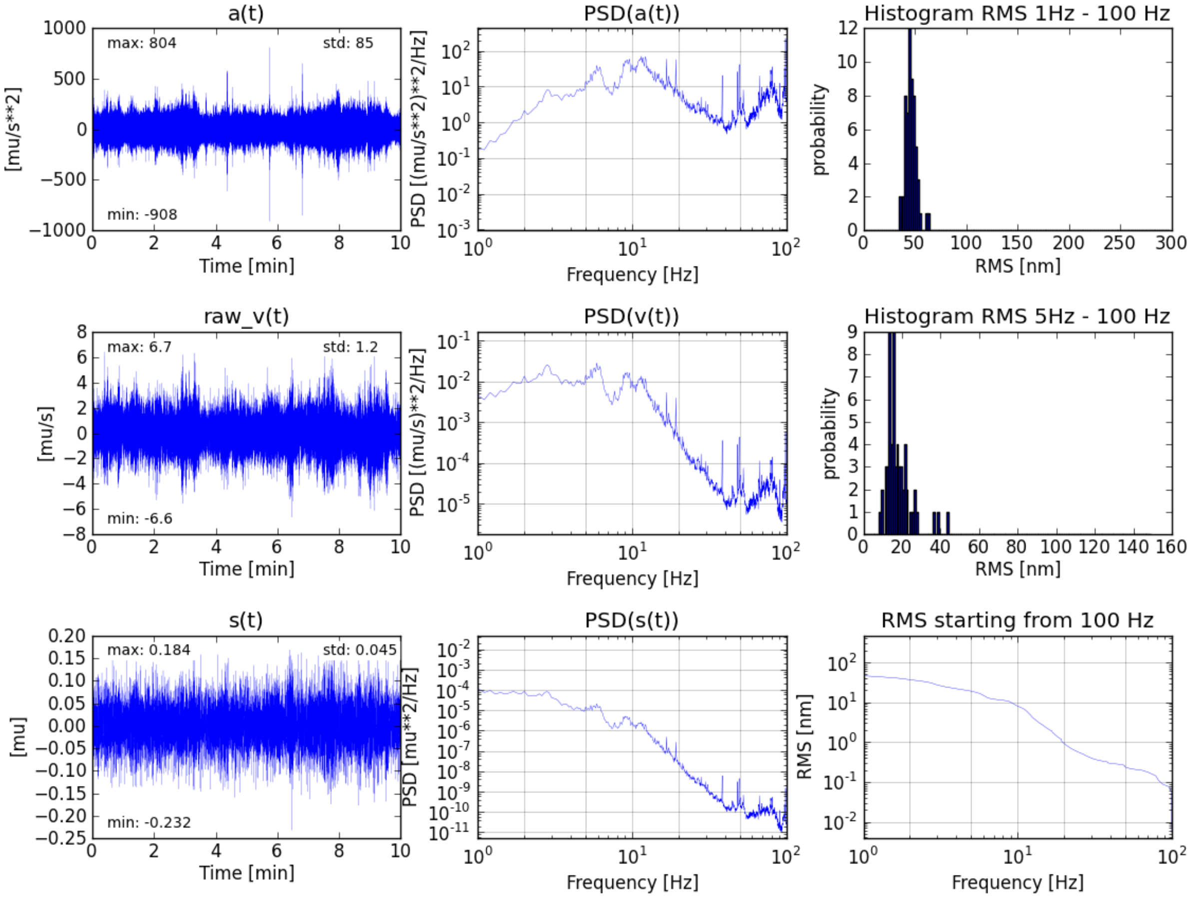

Fig. 16. *XTL at 2000m, 9:00am on 18-7-12*

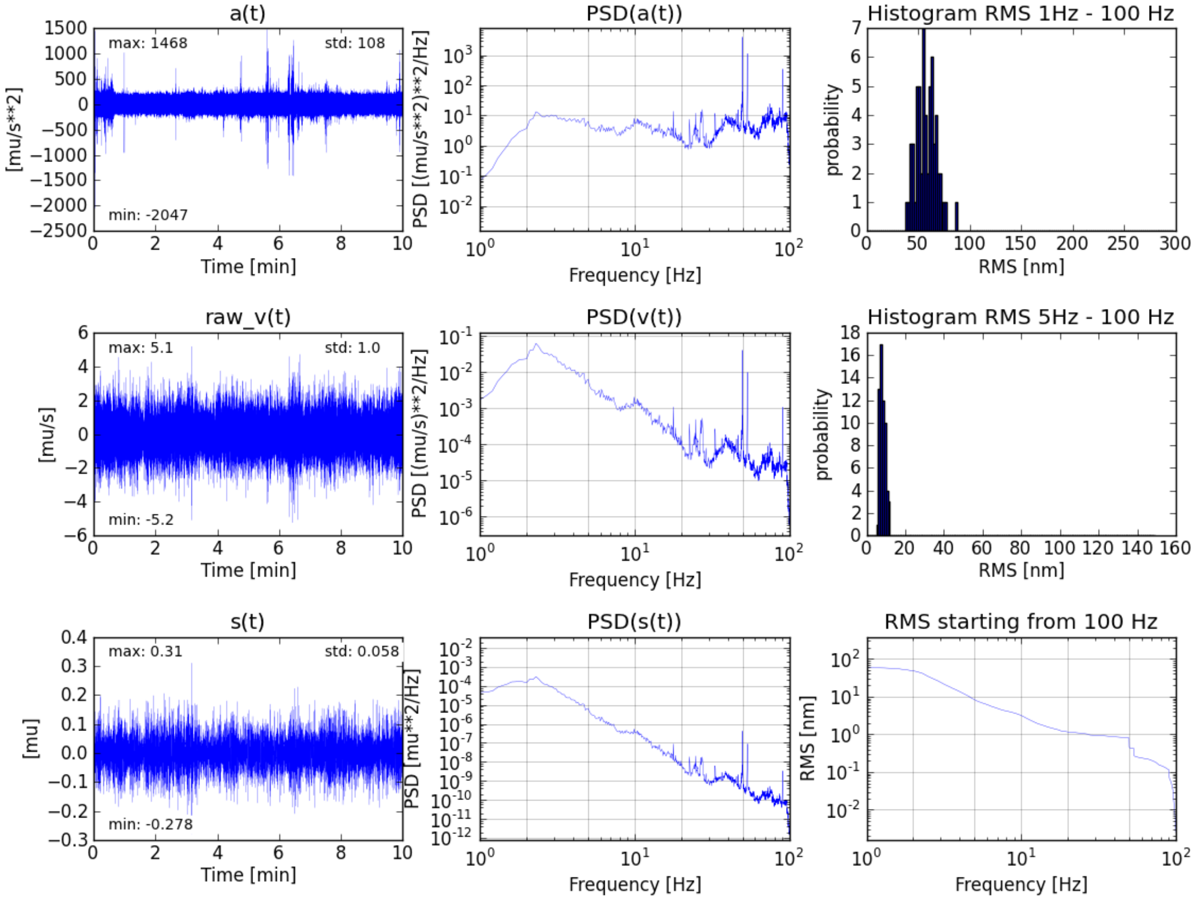

Fig. 17. *XTIN at 6th floor, 9:00am on 24-7-12*

21:00pm: This is the evening period

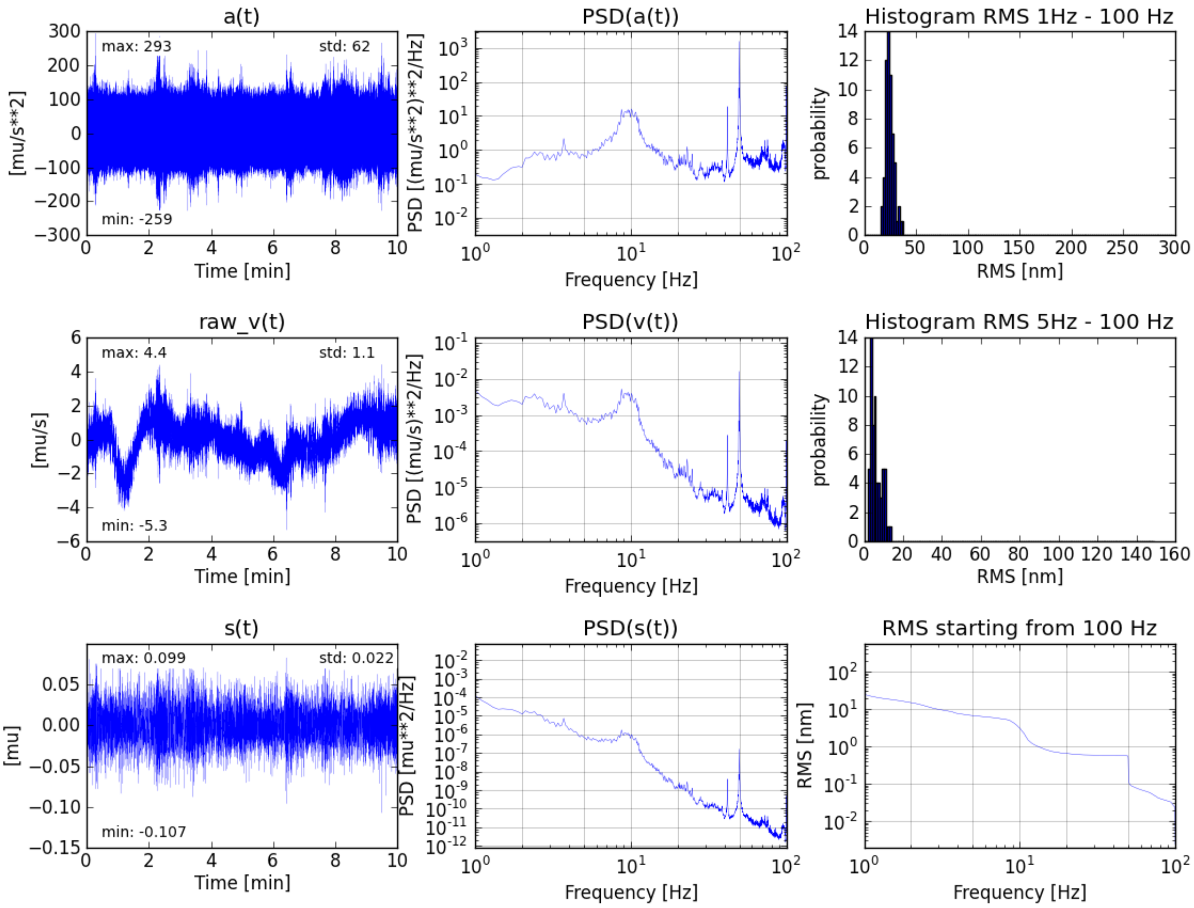

Fig. 18. *XHEXP1, 21:00pm on 22-6-12*

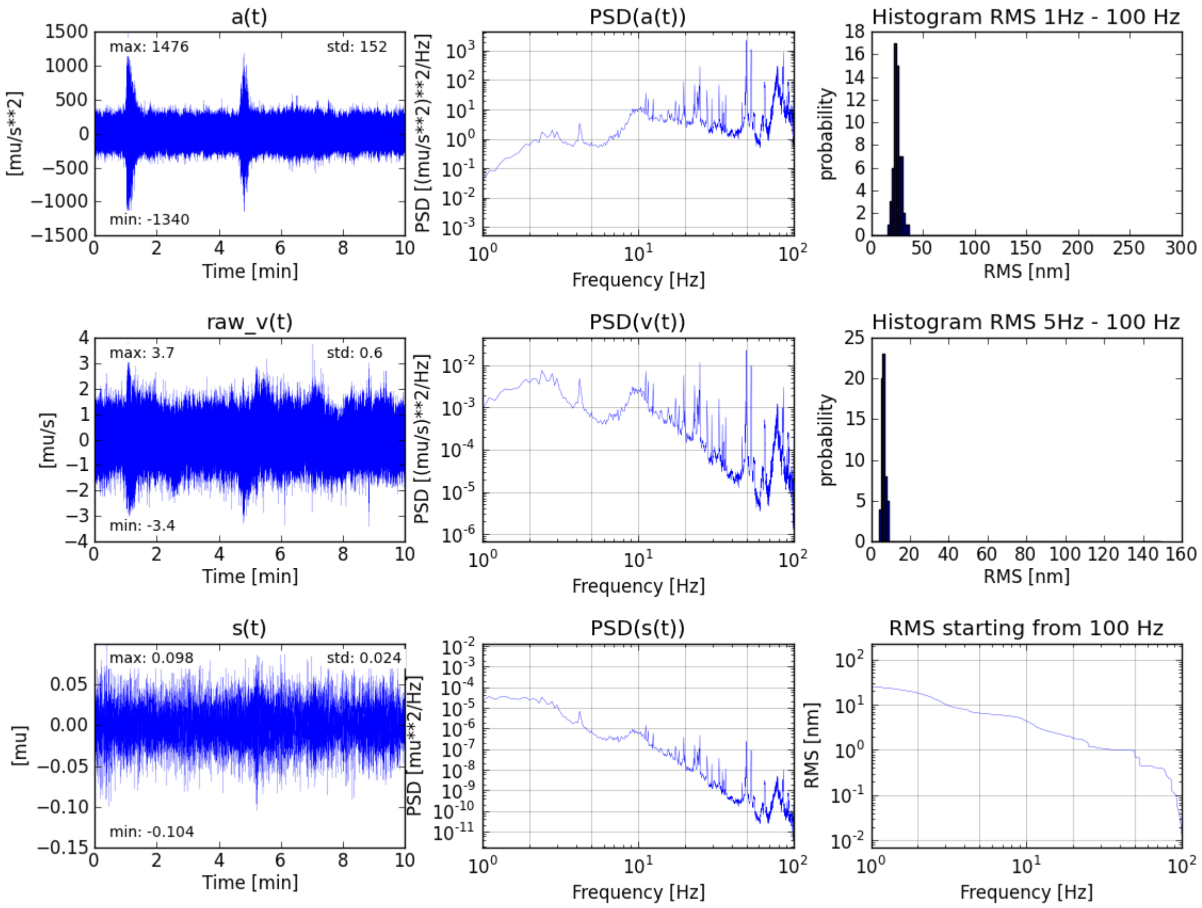

Fig. 19. *XTL at 100m, 21:00pm on 30-6-12*

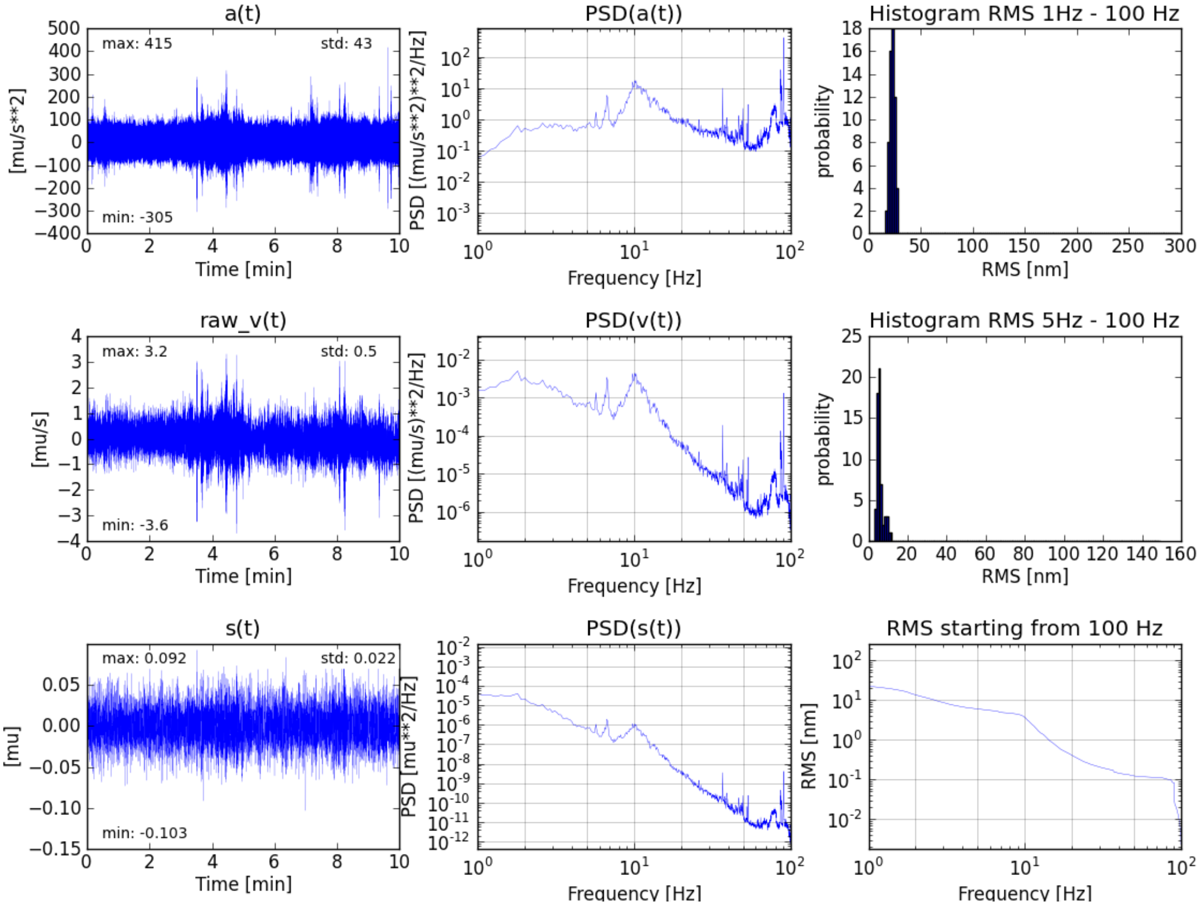

Fig. 20. *XTL at 1000m, 21:00pm on 4-7-12*

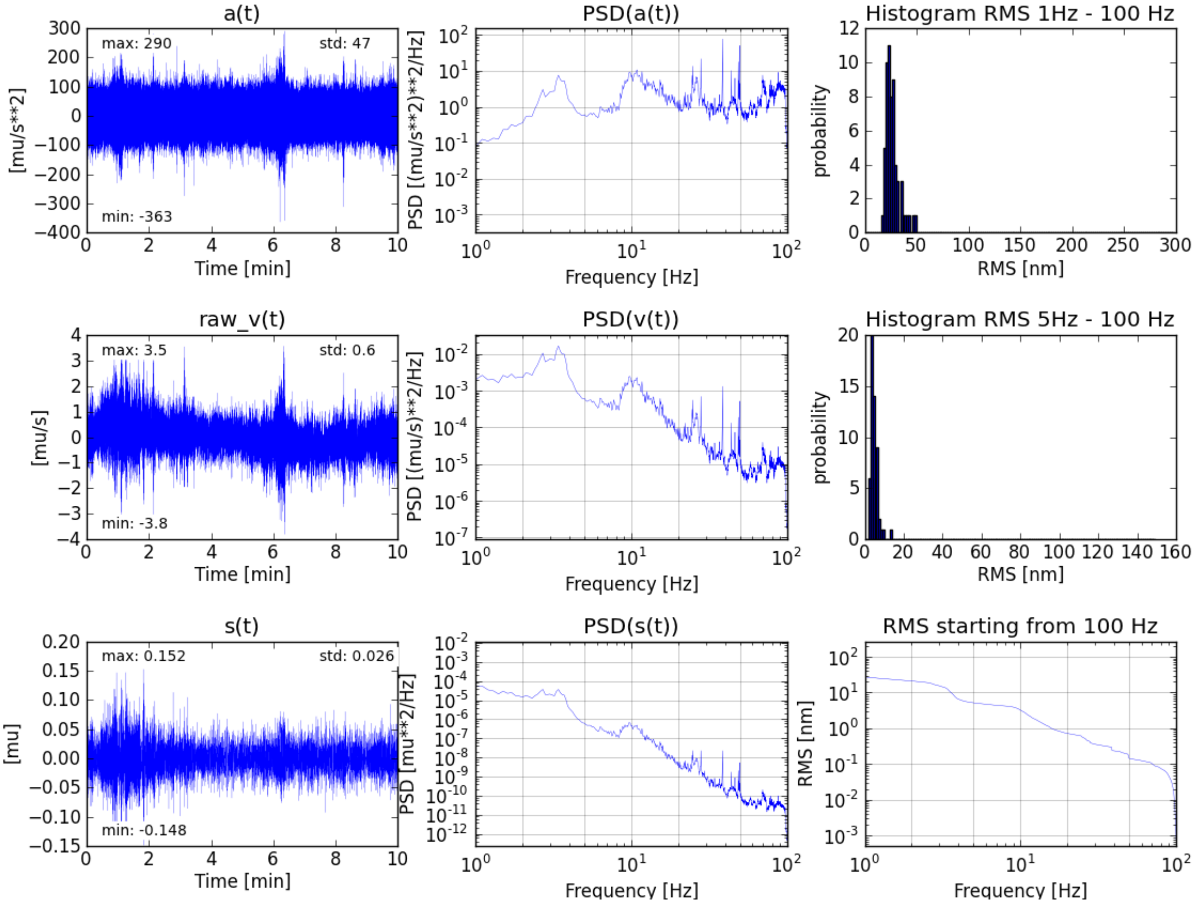

Fig. 21. *XTD6, 21:00pm on 6-7-12*

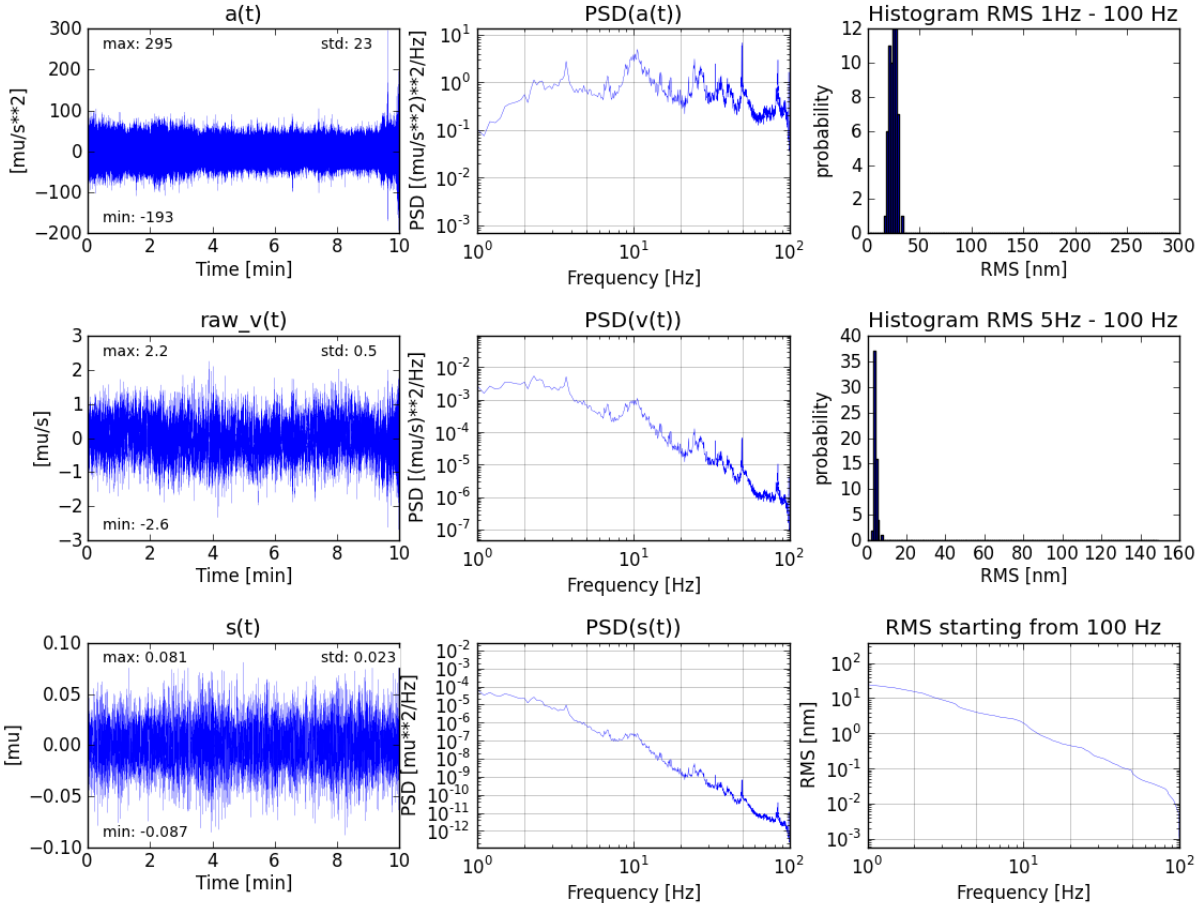

Fig. 22. *XTD1 at 300m, 21:00pm on 13-7-12*

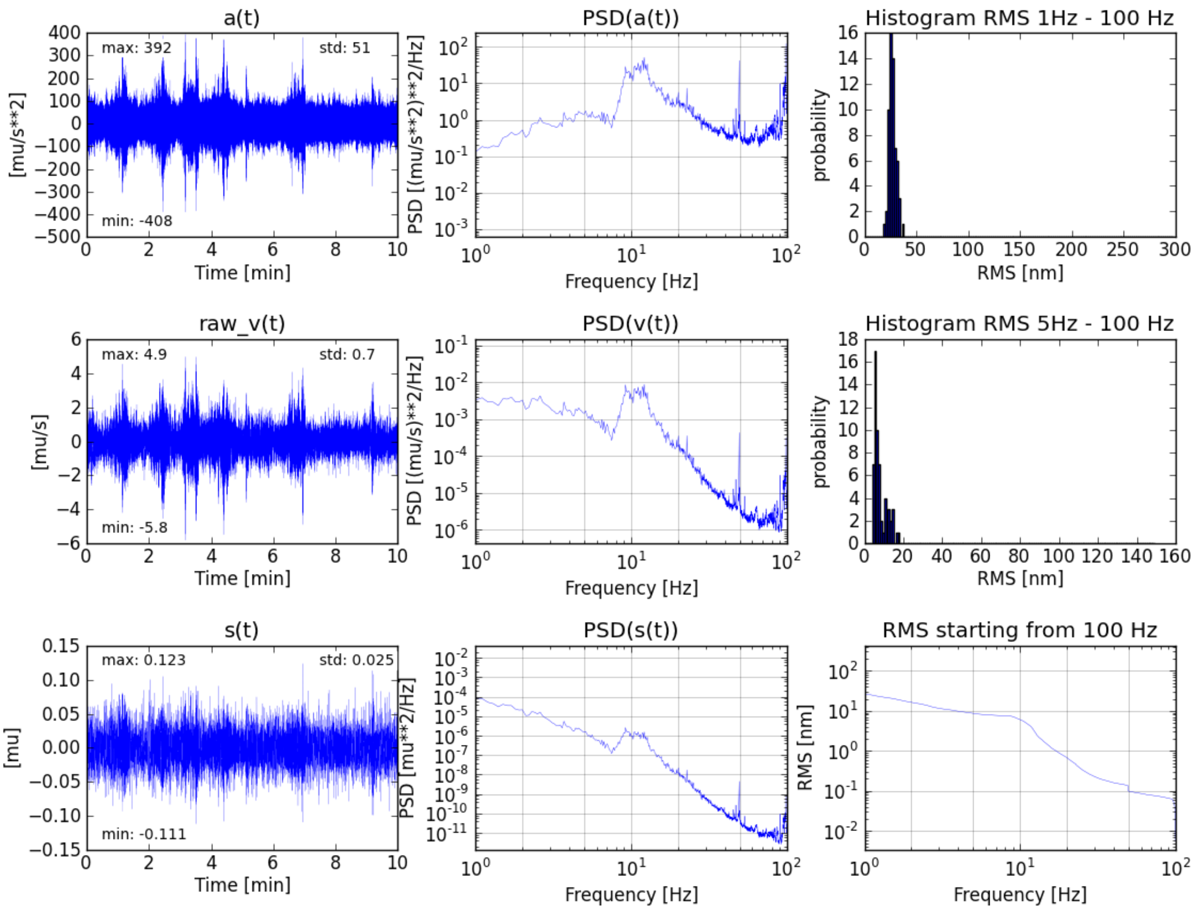

Fig. 23. *XTL at 2000m, 21:00pm on 18-7-12*

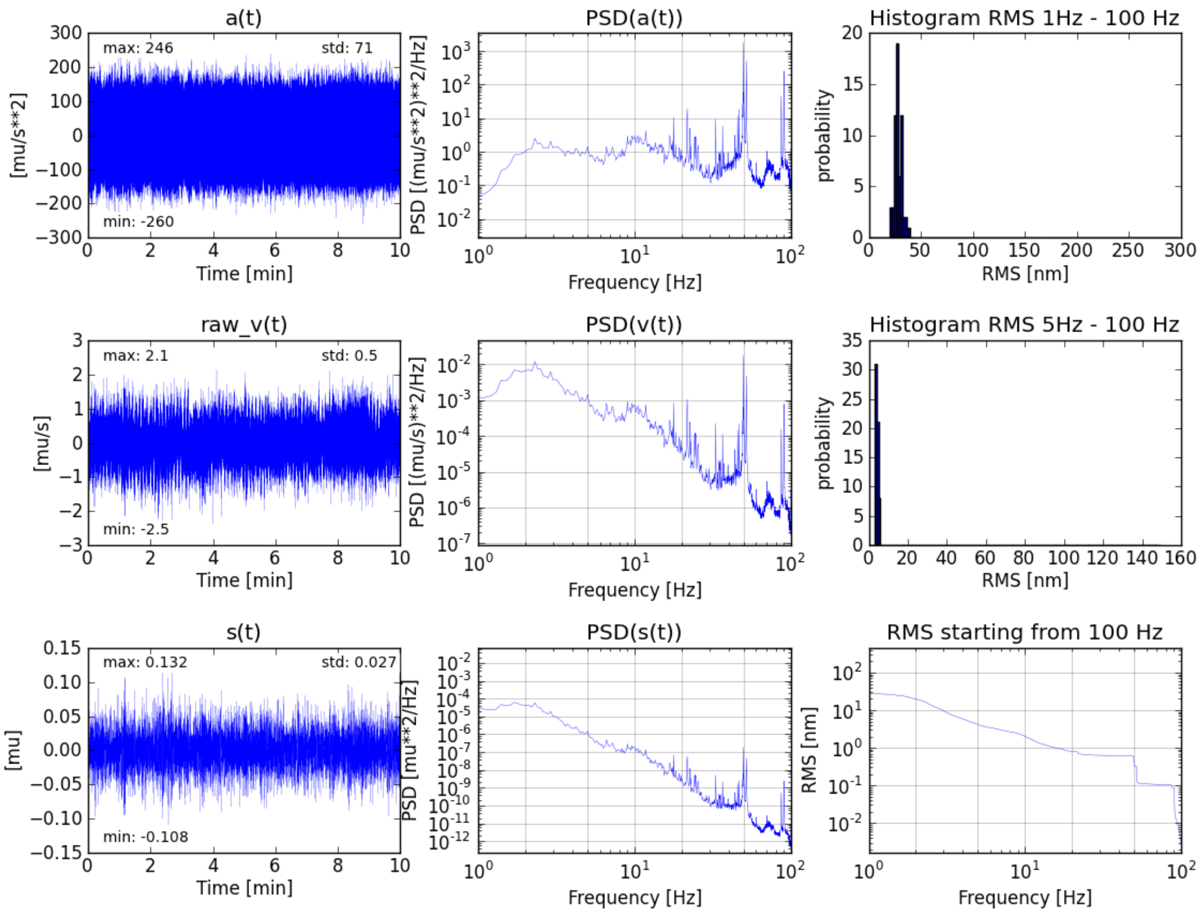

Fig. 24. *XTIN at 6th floor, 21:00pm on 24-7-12*

4.2 E-direction and N-direction results which represent the vibrations in the east and the north directions at XTL at 2000m, 3:00am

Besides the vibration in the z-direction which is important, the east and the north directions of all the sites are also recorded. The following plots are the vibrations in the east and the north directions at XTL at 2000m, 3:00am.

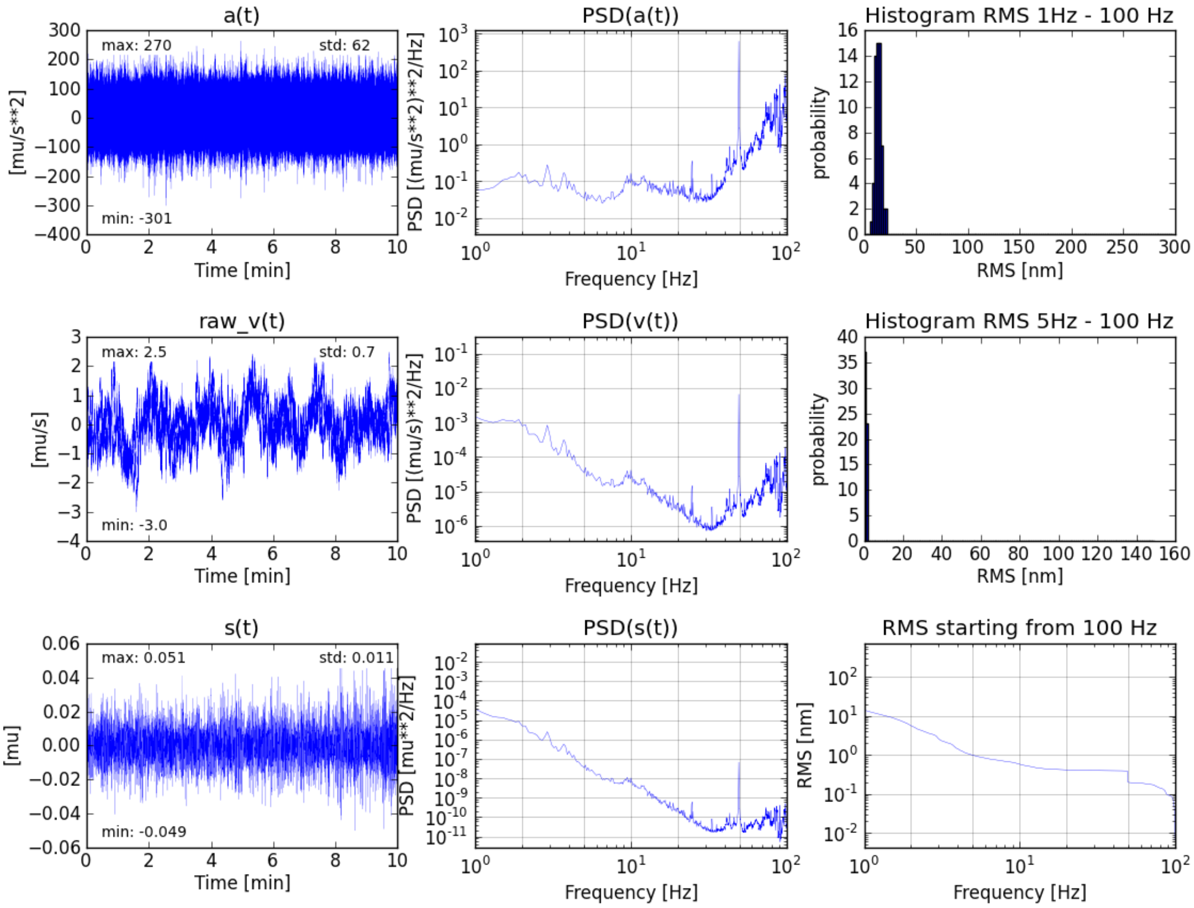

Fig. 25. *E-direction, XTL at 2000m, 3:00am on 18-7-12*

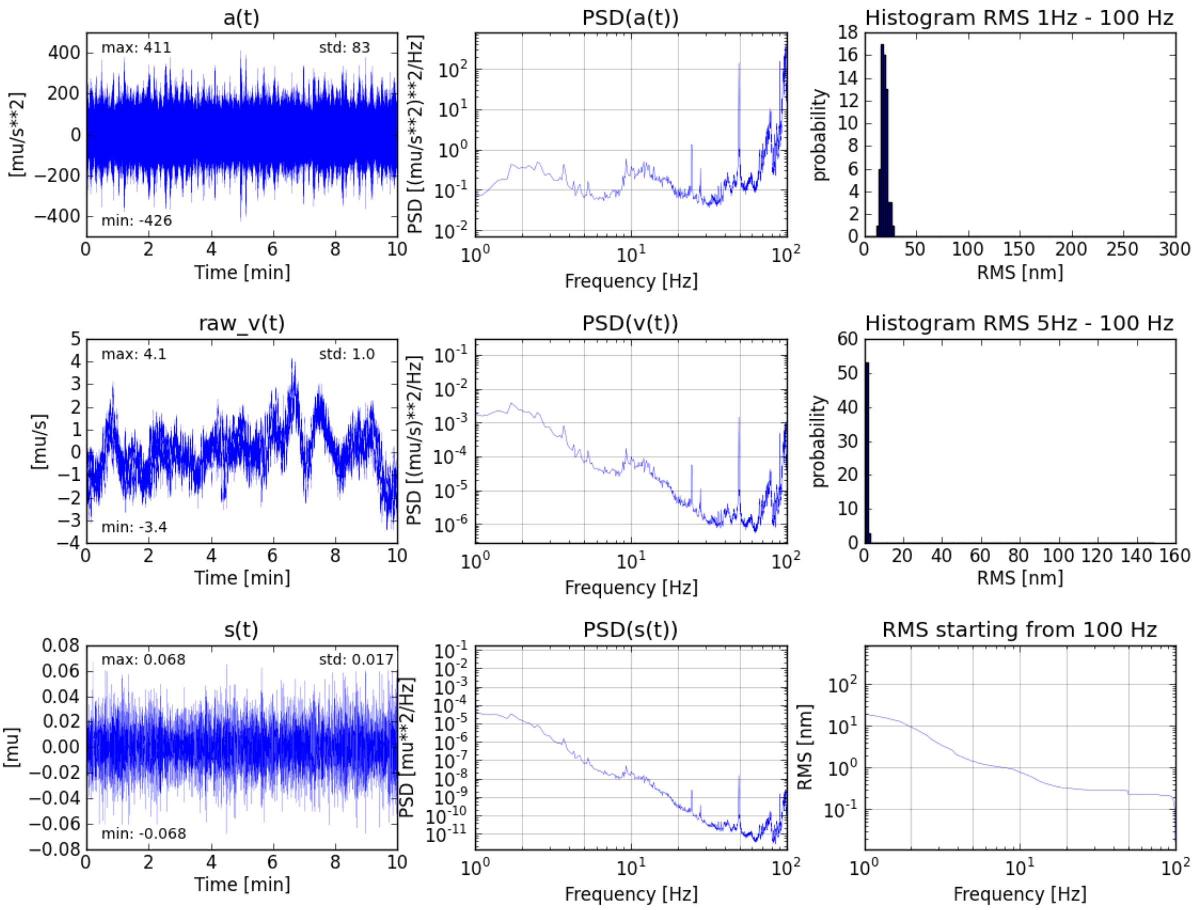

Fig. 26. *N-direction, XTL at 2000m, 3:00am on 18-7-12*

4.3 The comparison between the PSD (s(t)) plots of the 3 directions (z, e, n)

In order to compare the PSD of the displacements of the 3 directions (z, e, n), the data of the PSD(s(t)) of the 3 directions is extracted. The time period is also 10 minutes. It can be done in the same manner for PSD(v(t)) or PSD(a(t)) if needed.

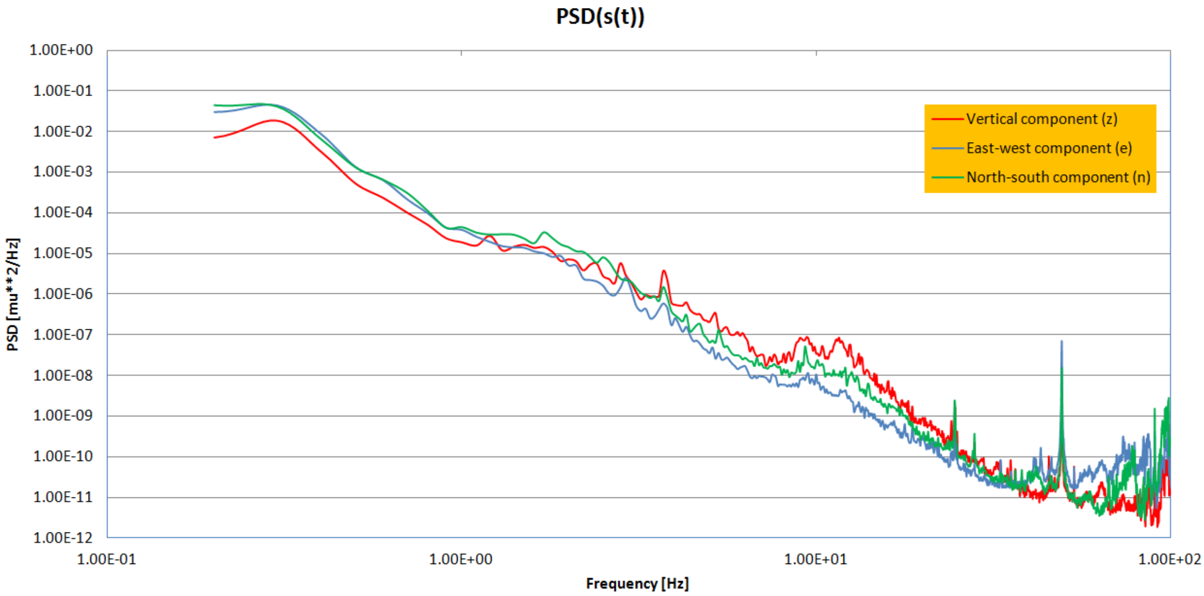

Fig. 27. *PSD(s(t)) plots of the 3 directions (z, e, n) at XTL at 2000m, 3:00am*

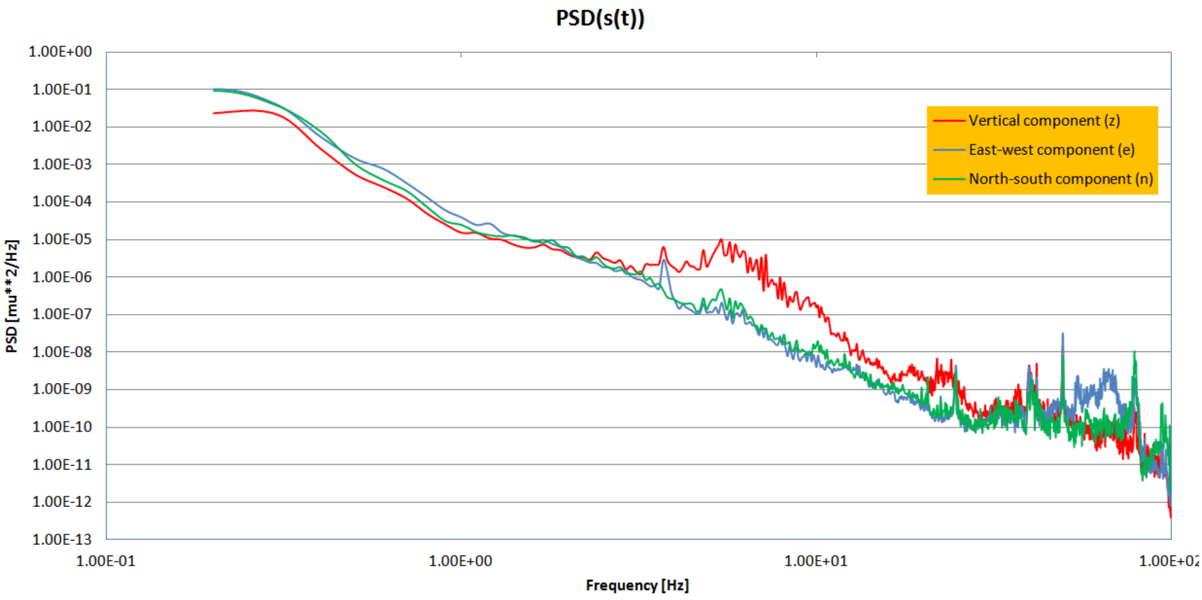

Fig. 28. *PSD(s(t)) plots of the 3 directions (z, e, n) at XHEXP1, 3:00am*

4.4 The comparison between the PSD (s(t)) plots of the z-direction at 3 different time periods

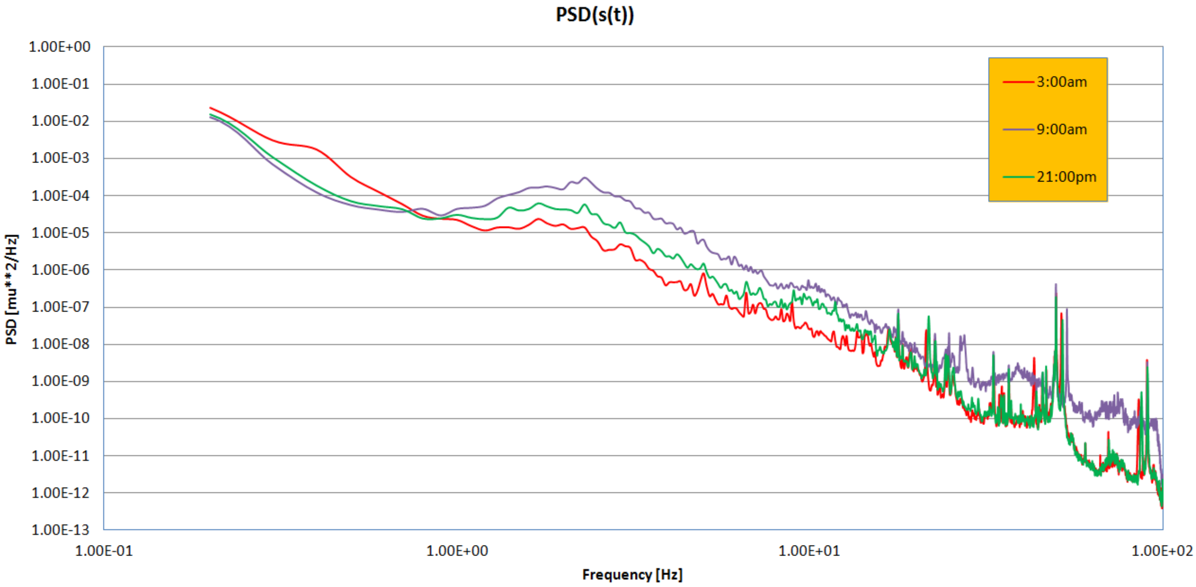

Fig. 29. *PSD(s(t)) plots of the z-direction at 3:00am, 9:00am and 21:00pm at XTIN, 6th floor*

The plots show that the difference between the vibrations in z-direction at 3:00am which is the most quiet time of the day and that at 9:00am which is the most noisy time of the day is around 10 times from 1Hz. Therefore, we can conclude that the cultural noise has its effect only from 1Hz.

4.5 The comparison between the PSD (s(t)) plots of the z-direction of all the measurement sites from 3:00am to 4:00am

Looking at the graph, we can see that the cultural noise from human activities like traffic and engineering works and the noise from the floors themselves have enhanced the ground vibration spectra. The reference spectrum was taken in 2004 at the very quiet site - Moxa, Germany. The time period for these plots is one hour.

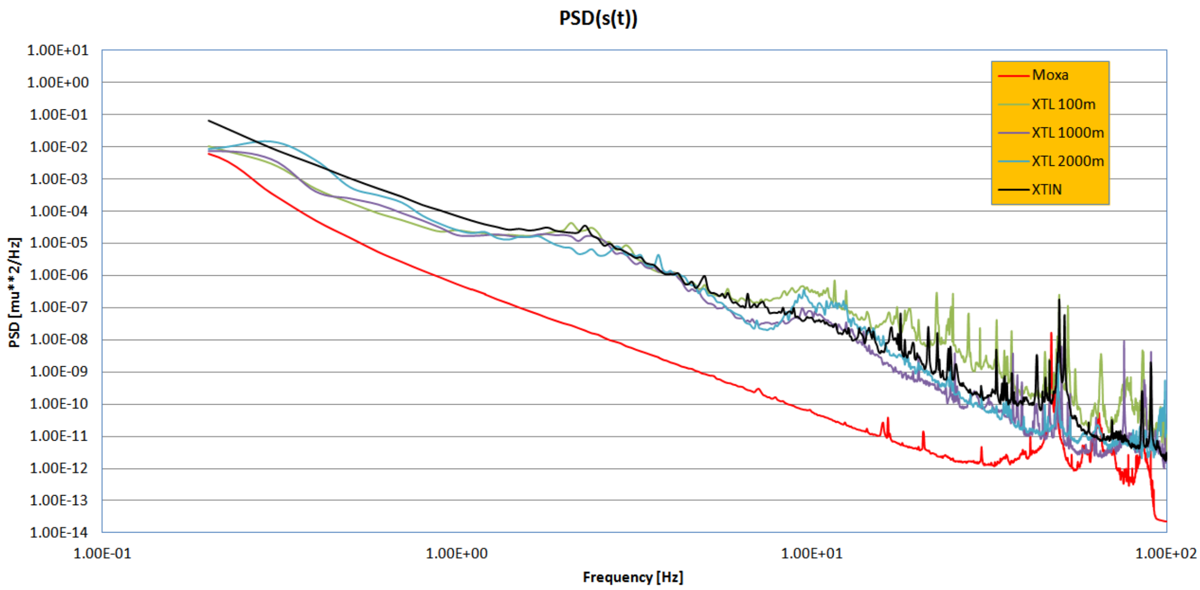

__Fig. 30.__ PSD(s(t)) plots of the z-direction at some measurement sites, from 3:00am to 4:00am

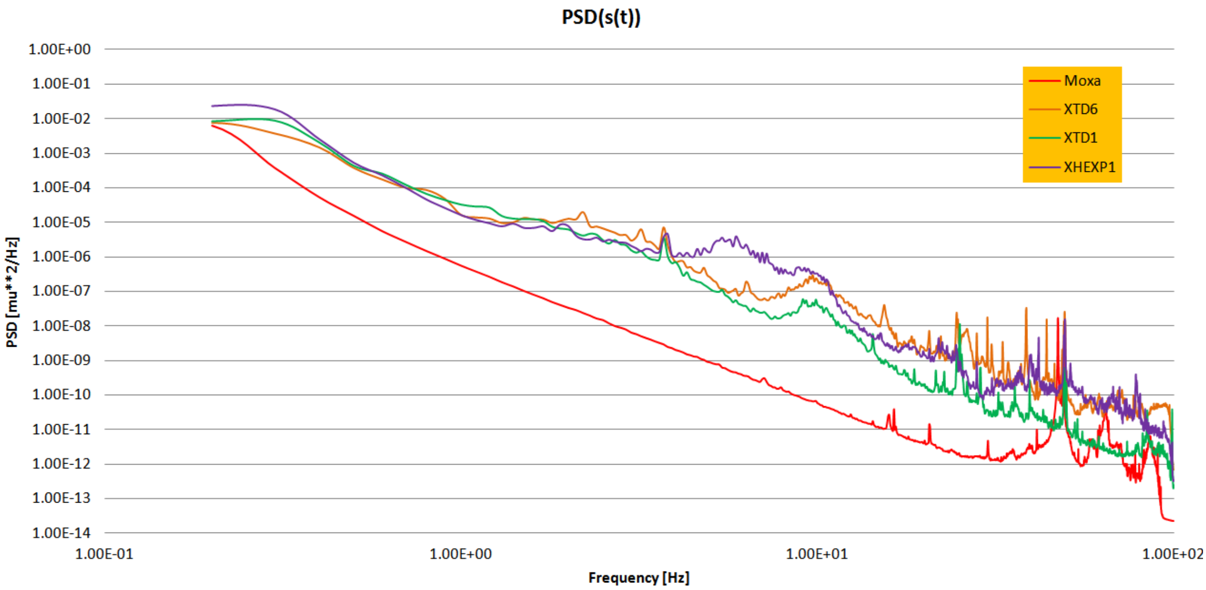

Fig. 31. *PSD(s(t)) plots of the z-direction at some measurement sites, from 3:00am to 4:00am*

The plots show that the difference between the vibrations in z-direction at our measurement sites and that at Moxa which is the very quiet area is of two orders from 1Hz.

5 Conclusions

The results show that the ground vibration measurements with the seismometer is a effective tool to evaluate the influence of noises on the stability of tunnels in which the synchrotron light will be set up. This influence should be corrected to get a more stable light sources in the XFEL facilities.

6 Acknowledgment

This report is a part of the result of an exchange programme in summer, 2012 in XFEL project, Desy GmbH, Hamburg, Germany. We would like to express our thanks to:

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Dr. Gerd Wellenreuther who wrote the Python code and helped us a lot in understanding and implementing the code.

Ms. Idoia Freijo-Martin who also helped us a lot in running the Python code.

Mr. Markus Hoffman, Mr. Schippel Joerg and other people who helped us in accessing the tunnels.

Besides our project, we really enjoyed our stay at Desy, appreciated all the people we worked with and shared a good working environment with.

Chao Ji

Hai Tran